Evaluation of GEM-MACH15 in the free troposphere by comparison with global analyses and models

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Introduction

BACCHUS is a bilateral project between Belgium and Environment Canada to develop modeling and assimilation tools for chemical weather applications. In this framework we continue the evaluation of the online GEM-MACH15 Air Quality forecast model running operationally above Canada. Last year we presented results which showed that GEM-MACH15 systematically underpredicts ozone in the troposphere and occasionally at the surface. Here, we look for the possible causes by comparing the most important species with the output of two global models of tropospheric chemistry: IFS-MOZART (European project MACC) and IMAGES, a low resolution CTM which is well validated on the climatological timescales. This comparison is performed on monthly averages above a few selected regions in North America, separating daytime values from nighttime values. This helps to clarify the causes of the ozone underprediction in the free troposphere by GEM-MACH15.

Materials and Methods

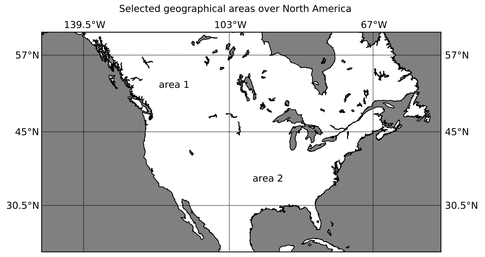
GEM-MACH15 is a r. MOZART 3 and IMAGES are global models having a grid resolution of 1° by 1° (resp. 2° by 2°).

- GEM-MACH15 (Anselmo et al., 2010): operational version 1.3.0a run on a rotated LAM grid above North America with horizontal resolution of 0.1375° by 0.1375° and 58 levels up to 0.1 hPa.
- IFS-MOZART (Flemming et al., 2009): main NRT product for MACC (f93i) where ECMWF NWP system IFS is coupled with global CTM MOZART3.5 (Kinnison et al., 2007). MOZART3 is run at 1.875° by 1.875° on 60 levels up to 0.1 hPa. Ozone and CO columns are assimilated into the system.
- IMAGES v2 ((Müller and and Stavrakou, 2005; Stavrakou et al., 2010) is a global CTM developed at BIRA-IASB. The results shown here use bottom-up emission inventories (not optimized with satellite observations). The model is run at 2° by 2.5° on 40 levels up to 44 hPa.

The details of the comparisons are:

	GEM-MACH15 vs. MOZART3	GEM-MACH15 vs. IMAGES
period	january 2010 & july 2010	january 2010 & july 2010
geogr. area	selected regions of North america as shown below	selected regions of North america as shown below
data	average of 31 snapshots at 21UT	average of 31 daily means

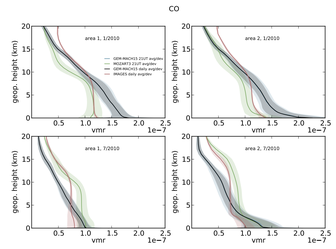
The average over a given region was computed from *all* gridpoints that fell within the region.



Results: Long-lived species

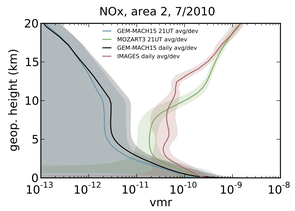
CO

Among the 3 models GEM-MACH15 shows the largest seasonal variation. It shows a unrealistically high vertical gradient, pointing to a lack of vertical mixing (see also results of OH). MOZART3 shows very little seasonal variation (note that total columns observed by IASI are assimilated into this model).



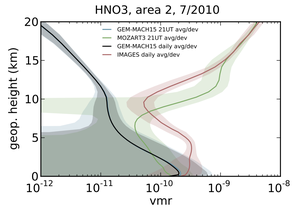
NOx

GEM-MACH15 seriously underestimates the gradient of NOx, by up to 2 orders of magnitude at the tropopause. This again indicates a lack of vertical mixing in GEM-MACH15 . Furthermore, there is a lack of important NOx sources, such as lightning, and aircraft emissions.



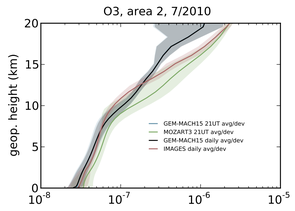
HNO3

The underestimation of NOx in free troposphere naturally leads to the underestimation of HNO3. We note remarkably good agreement between GEM-MACH15 and the other models at the surface.



O3

As shown at IWAQFR 2010, ozone is underestimated in the free troposphere by about 50%. Again, this is related to the underestimation of NOx. Note that the MOZART results are obtained with assimilation of satellite observations of the total (OMI, SCIAMACHY) and partial (SBUV) columns.



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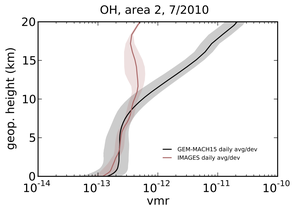
Results: Short-lived species

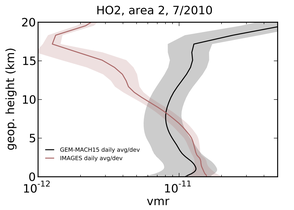
OH

OH is similar in all models in the lower troposphere, indicating that the differences seen in CO are due to differences in transport.



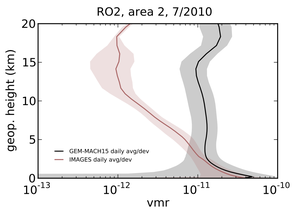
HO2

HO2 results are consistent with OH showing very overestimated values above 12km.



RO2

substantial overestimation of RO2 above 5km can be attributed to underestimation of no, because reaction with no is the main ro2 sink, espacially at these altitudes



Conclusions

- In most cases the 3 models agree well in the lowermost layers.
- There seems to be a serious lack of vertical mixing in GEM-MACH15, resulting in an irrealistic decrease of CO with altitude. This impacts negatively all results in the free troposphere. Convection should be applied to chemical tracers, and the values of the vertical diffusion coefficients should be checked.
- Above the surface, GEM-MACH15 severely underestimates NOx. This impacts negatively all results in the free troposphere. The special sources of NOx should be added: production by lightnings, emissions by aircraft flights, production by N2O + O1D.

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